



The Heartbeat behind Portable Medical Devices: Ultra-Low-Power Mixed-Signal Microcontrollers

The proliferation of sophisticated yet affordable personal medical devices is transforming the health care industry, enabling consumers to monitor vital signs and other key aspects of their health at home and on the go, without costly and inconvenient visits to the doctor's office. According to Gartner, portable consumer medical devices, such as blood glucose monitors, blood pressure monitors, insulin pumps and heart rate monitors, represent the fastest-growing segment in the medical equipment market. A recent medical semiconductor report by Databeans also projects that the home medical device segment will grow by 9 percent (combined annual growth rate or CAGR) over the next five years.

The explosive growth of the personal medical device market stems from a variety of factors: a steadily "graying" (aging) population requiring more frequent health monitoring, skyrocketing costs of traditional physician-directed medical care, growing consumer awareness of the benefits of wellness products, widespread availability of personal medical devices online and in retail outlets, and the increasing sophistication, ease of use and affordability of these consumer health care products enabled by continuous advances in semiconductor technology.

While consumer products are generally price sensitive, the consumer portable health market adds other stringent requirements to be successful in the market. Above all, they must be very reliable and accurate to prevent health problems. These requirements are regulated by government entities such as the Food and Drug Administration (FDA) in the United States.

To succeed in the increasingly competitive home health care market, portable medical devices should offer the following features:

- Ease of use
- Highly reliable and safe (government-regulated) operation
- Easy, secure connectivity
- Low-power operation (i.e., long battery life)
- Support for a wide range of voltages (especially lower voltages)
- High measurement accuracy
- Small form factors
- Affordable cost

To deliver this array of product features to consumers at economical prices, medical device developers must reduce system cost by limiting the number of discrete components within the design. Semiconductor suppliers also are tasked with supplying highly integrated embedded control solutions that enable increased performance and reliability within strict power and cost budgets. At the heart of these portable device designs are highly integrated mixed-signal microcontrollers (MCUs) designed to deliver exceptional processing performance at the lowest supply currents.

Ease of use is essential for all portable medical products because it reduces errors in measurement resulting from operator error. Such devices should require minimal user interaction for proper operation, simple user input (for example, fewer buttons and simpler software menus) and large, easy-to-see displays (e.g., large LCDs with backlighting). To support these features, MCUs must provide field-programmable non-volatile memory storage (typically in-system programmable flash memory), as well as flexible I/O configurations to make the best use of limited pins.

While many portable medical devices today simply display health monitoring results and leave the interpretation and logging to end users and their physicians, newer devices feature simple connectivity to log and transmit results automatically. Typically, these more sophisticated products will connect to personal computers or mobile health appliances with software that can track results, or they will securely transmit information wirelessly to medical professionals, caretakers or web-based applications—a practice known as telemedicine.

The health care equipment market has adopted an optimized USB device standard, the Personal Health Care Device (PHCD) Class, which leverages the ubiquitous USB interface to enable standardized transmission of data and messages, regardless of device manufacturer. Moving forward, wireless transmission of data will make connectivity even easier with simple yet reliable wireless connections for even greater convenience. MCUs will need to provide a variety of integrated connectivity interface methods such as integrated USB controllers with precision oscillators.

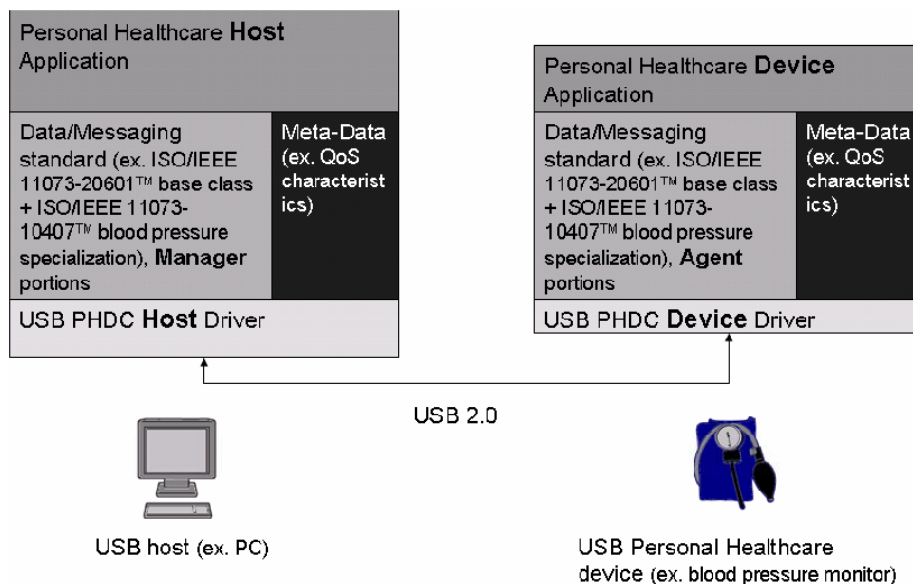


Figure 1: USB Personal Healthcare Device Class Supports Easy Connectivity

RF transmitters and transceivers working in concert with MCUs can enable wireless connectivity for telemedicine applications. In addition, wireless MCUs—highly integrated devices that combine a low-power MCU core with a high-performance RF transceiver in the same package—are now widely available. Silicon Labs' Si10xx wireless MCUs, for example, provide the ultra-low-operation required by battery-powered portable medical applications, coupled with extended range and exceptional RF sensitivity enabled by an integrated sub-GHz transceiver.

Whatever the connectivity method or system architecture used, communication protocol stacks will require more code space in the MCU. As a result, more memory in smaller footprint devices will be in increasing demand.

While choices in high-performance yet low-power MCUs and communications options will be important, all medical devices will measure some physical parameter to quantify some aspect of a person's health (e.g., blood pressure or oxygen levels). This requires the ability to sense and measure light (for blood oxygen), conductivity (for blood glucose), pressure (for blood pressure) and temperatures; and these measurements must be highly accurate and consistent. In the health care market, there is simply no room for errors in measurement.

Mixed-signal MCUs must give superior analog voltage measurement results in the presence of noisy digital processor and communications signals in small spaces. This is one of the most challenging engineering problems faced by semiconductor suppliers and such specifications will be scrutinized by product engineers, especially when faced with low battery voltages for the IC. Measurements must be low in noise and distortion (good signal-to-noise and distortion ratios) and highly linear. Analog-to-digital converter (ADC) operation must be allowed even when the MCU is in operation as the end user will expect to observe functions during measurement, and it is likely the MCU will interpret results in real-time. Furthermore, all chip features should be permitted even at the lowest battery voltages; what good is the MCU if you cannot make a measurement over the full battery life? In short, MCU suppliers in this market must integrate accurate analog measurements without compromise.

The next design challenge for the MCU supplier is the demand for long battery life in the end product. "Portable" generally means that the device is battery powered. Typically, added features result in greater power consumption, but developers will not design a portable medical product that requires end users to use large, heavy batteries or change them frequently.

MCUs must support three parts of a low-power strategy: low power while in active mode, low power while in standby mode, and reduced time in an active state. The portable device, and thus the MCU, will be in an off or lower power state most of the time; however, it will often maintain some sort of function such as clock/calendar or alarm when not in use. While active power consumption is important, minimizing the time awake is the key to extending battery life. MCU designers must engineer ways to wake the MCU clock and analog circuits for fast measurements and then allow the MCU to settle back to a low-power state. For example, making a voltage measurement with an ADC requires a voltage reference. Such voltage references typically require tens of milliseconds to turn on and stabilize before a measurement can be made. During this time, the MCU is on and draining the battery.

Silicon Labs' ultra-low-power C8051F9xx MCUs wake up in microseconds like many power-efficient MCUs, but the on-chip voltage reference is designed to also wake within 2 microseconds, allowing accurate ADC measurements to begin quickly. The ADC is also designed to rapidly accumulate many measurements without CPU intervention for improved results while further minimizing time awake. The less time awake, the less current is drawn on the battery while giving good results.

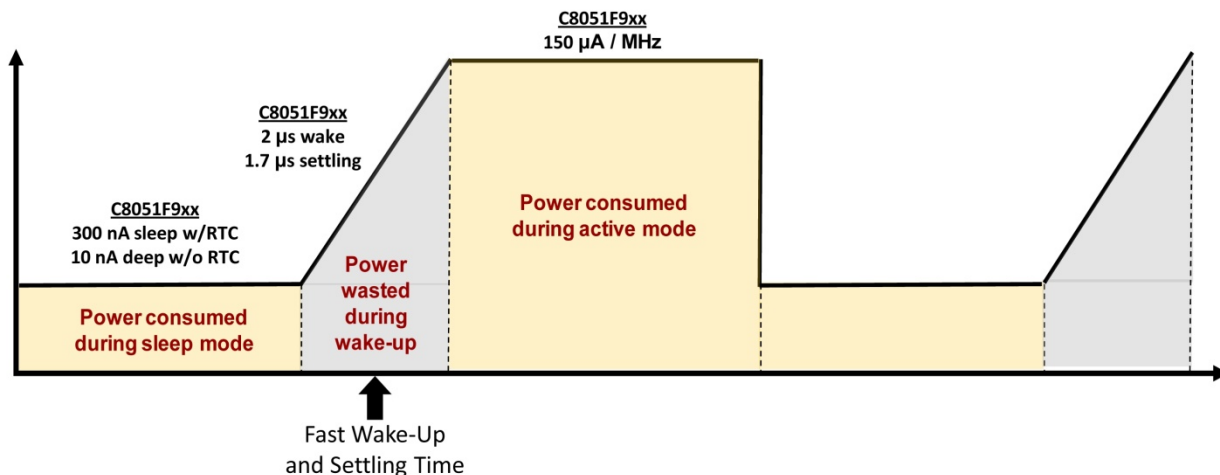


Figure 2: Fast Wake Times and Short Operation Intervals will Extend Battery Life

Another important trend in MCU design involves supporting new battery use configurations and technologies. Rechargeable batteries are popular and typically need higher voltage support, and integrated on-chip voltage regulators are mandatory. An emerging trend is to use only one alkaline battery to reduce product size or to save cost when the end user expects the supplier to ship an installed battery. Until recently, this approach required the added cost and space of a discrete dc-dc switching regulator to boost the alkaline battery voltage for proper MCU operation (alkaline batteries have a useful life to 0.9 V). Not only do these switching regulators create a large amount of noise in voltage measurements, they must remain on at all times to allow the MCU to wake from sleep mode, thereby draining power and reducing battery life.

Sophisticated low-power MCUs such as Silicon Labs' F9xx devices include an integrated dc-dc regulator that addresses these issues. The result is lower noise, less cost, reduced footprint, and better control allowing the dc-dc regulator to be off while the MCU is in its low-power state, extending battery life. Even though this dc-dc regulator is integrated, it should still output the boosted voltage supply externally to the rest of the system for a true low-power, single-battery solution.

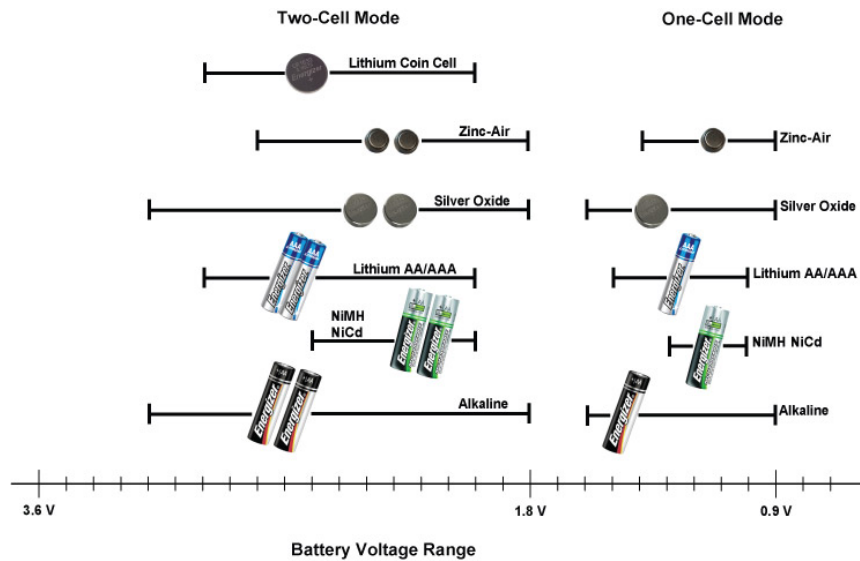


Figure 3: MCUs should Support a Wide Range of Voltages Supplied by Batteries

While MCU suppliers continue to innovate and integrate power- and battery-saving features, the trend toward energy efficiency would not be fully advantageous if the cost and footprint of the MCU grew substantially. The goal is to help the embedded developer deliver a lower cost, smaller end product, as well as reduce power consumption. Such solutions must reduce the bill of materials *and* size. The best MCUs will deliver plenty of performance, integrated connectivity, memory and superior analog peripherals in the smallest form factors. In other words, semiconductor suppliers must provide increased *functional density* without compromise.

Note the ultra-low-power MCU example below—64 kB of flash code storage, 4 kB of data RAM, an ADC, and two voltage regulators (LDO and boost regulator) within a 4 mm x 4 mm footprint (in some cases even smaller). This compact mixed-signal MCU design allows a complete measurement and interface system on a single chip without sacrificing performance or battery life. Product designers will be careful to choose MCUs like this with just the right set of peripherals to obtain the optimal cost/performance benefit.

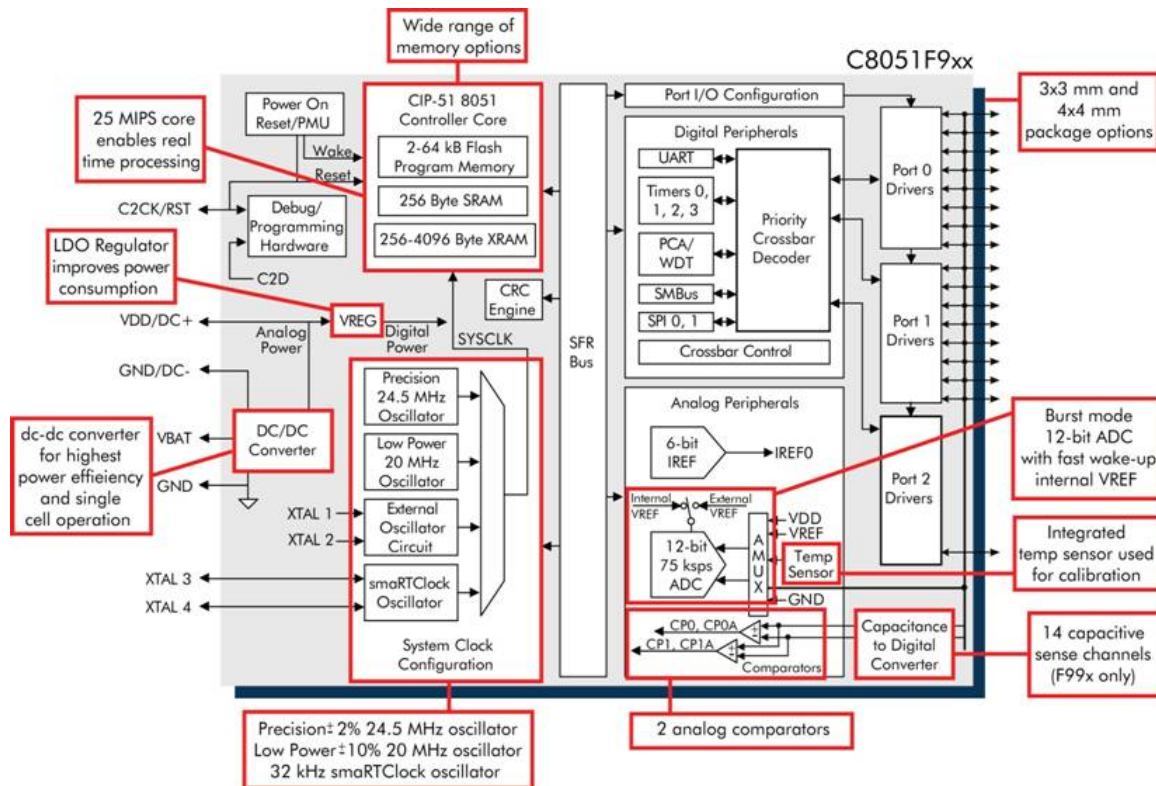


Figure 4: C8051F9xx Block Diagram

Embedded developers and product managers are under continuous pressure to push the envelope of cost, size, power consumption and performance in their next portable medical device designs. The answer is to use highly integrated mixed-signal MCUs to deliver products to a market that demands the very best in performance and affordability in the smallest form factors. Functionally dense mixed-signal MCUs will provide the heartbeat for the next generation of portable medical devices, and healthcare equipment makers that deliver optimized products that meet consumer needs will enjoy the benefits of this fast-growing market segment.